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SYMPOSIUM ON THE RECOGNITION AND CLASSIFICTION OF AURAL (NON-SP--ETC(U)
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Report No. 4376

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Symposium on the Recognition and Classification of Aural (Non-Speech) Signals

Final Report

April 1980

Prepared for:
Office of Naval Research
Engineering Pyschology Programs

80 5 23 059

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: 4736
2. GOVT ACCESSION NO.: AD-A084 723
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): SYMPOSIUM ON THE RECOGNITION AND CLASSIFICATION OF AURAL (NON-SPEECH) SIGNALS
5. TYPE OF REPORT & PERIOD COVERED: Final
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): Dr. David J. Getty; Dr. James H. Howard, Jr
8. CONTRACT OR GRANT NUMBER(s): N00014-78-C-0234
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Bolt Beranek and Newman Inc., 50 Moulton Street, Cambridge, Massachusetts 02238
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: NR196-154
11. CONTROLLING OFFICE NAME AND ADDRESS: Engineering Psychology Programs, Office of Naval Research
12. REPORT DATE: April 1980
13. NUMBER OF PAGES: 25
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Same
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited. Reproduction in whole or part is permitted for any purpose of the United States Government
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number): perception, pattern recognition, classification, identification, visual perception, auditory perception, multidimensional scaling
20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

A Symposium on the Recognition and Classification of Aural (Non-Speech) Signals was held at Bolt Beranek and Newman Inc. in Cambridge, Massachusetts, between June 28 and June 30, 1978. The meetings were attended by approximately 40 participants and observers. Thirteen papers were presented by invited speakers covering the fields of human auditory perception, human visual perception, theoretical and machine approaches to pattern recognition, and multidimensional scaling theory.

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The purpose of the symposium was to determine the current state of knowledge regarding the theory of complex-signal recognition and classification, empirical tests of these theories, and significant implications of this work for applied recognition and classification systems.

The papers presented at the symposium are being published by Lawrence Erlbaum Associates in a volume entitled Auditory and Visual Pattern Recognition, edited by David J. Getty and James H. Howard, Jr. The book will be released in 1980.

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SYMPOSIUM ON THE RECOGNITION AND CLASSIFICATION
OF AURAL (NON-SPEECH) SIGNALS

ONR Contract Number N00014-~~6~~78-C-0234
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April, 1980

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ACKNOWLEDGEMENTS

This symposium was supported jointly by the Engineering Psychology Programs of the Office of Naval Research and by the Naval Ship Research and Development Center. We thank Dr. Martin A. Tolcott, Director of ONR's Engineering Psychology Programs, Dr. John J. O'Hare, Assistant Director of Engineering Psychology Programs, and Dr. Arthur E. Bisson of NSRDC for their encouragement and support in organizing the symposium, and for their patience through the process of publishing the volume of papers based on the conference proceedings.

We thank Dr. John A. Swets for his summary remarks and discussion of the proceedings that concluded the conference. We are grateful also to Mildred C. Webster for her resourceful management of the endless details of the conference.

The purpose of this project was to organize and conduct a symposium on the recognition and classification of complex (non-speech) auditory and visual signals. The primary objective of the symposium was to determine the current state of knowledge regarding the theory of complex signal recognition and classification, empirical tests of these theories, and significant implications of this work for applied recognition and classification systems. The meetings also served to define some of the problem areas in theory and research, and to predict promising directions for future work.

The symposium was held at Bolt Beranek and Newman Inc. in Cambridge, Massachusetts between June 28 and June 30 of 1978. The co-organizers of the symposium were David J. Getty of Bolt Beranek and Newman Inc. and James H. Howard, Jr. of The Catholic University of America. Thirteen invited speakers participated in the meetings, covering the fields of human auditory perception, human visual perception, theoretical and machine approaches to pattern recognition and classification, and multidimensional scaling theory. The program of the symposium is given in Appendix A; a list of the attendees is given in Appendix B.

Prior to the symposium we reached an agreement with Lawrence Erlbaum Associates, Inc. that they would publish the papers presented at the meeting in a hardcover volume, tentatively entitled <u>Auditory and Visual Pattern Recognition</u>. In the months

following the meeting, we ultimately received manuscripts from twelve of the thirteen conference speakers. Each manuscript was reviewed and edited by Getty and Howard, as editors of the volume, and, if required, revised by its author(s). The final revisions of these manuscripts have now been sent to L. Erlbaum Associates for typesetting. Our expectation is that the volume will be released early in the fall of 1980.

The contents of the volume are summarized by the following set of chapter abstracts:

SECTION I: PERCEPTION OF COMPLEX AUDITORY PATTERNS

CHAPTER 1: Pitch Perception: An Example of Auditory Pattern Recognition

Frederick L. Wightman

Northwestern University

Modern research in psychoacoustics has provided an impressive body of data on the auditory system's response to simple stimuli such as pure tones and clicks. Of course, it has always been clear that our eventual goal is to understand the processing of more complex stimuli, such as speech and music. One important feature of many complex stimuli is that they evoke the perception of pitch. Neither the exact physical characteristics of stimuli which lead to this percept, nor the nature of the auditory processing which mediates it are known at present. The greatest challange for theories of pitch perception is to explain the invariance of the percept. Many sounds which have very different physical features (both temporal and spectral) have the same pitch; there is clearly no simple physical correlate of the pitch percept. Modern theories treat pitch perception as a kind of auditory pattern-recognition, in which the central auditory system extracts pitch by some set of operation on "patterns" of neural activity supplied by the periphery. While the theories differ in many ways, all are remarkably successful in accounting for the empirical data and

there is little reason to favor one over another. Recent research from our laboratory on pitch perception in hearing-impaired listeners may provide critical tests of certain key features of the current theories. Our principal concern at present is the relative importance of spectral and temporal cues. It is our hope that these experiments will be revealing, about pitch perception in particular, and about auditory function in general.

CHAPTER 2: Perception of Sound Signals at Low Signal-to-Noise Ratios

Reinier Plomp

Institute for Perception TNO

In practice sound signals to be recognized and classified are usually presented against a background of noise. The perceptual uncertainty introduced by the noise may lead to the imagined perception of signals which were actually not present. This will be explained on the basis of experiments on the perceived continuity of a tone alternated with noise, triadic comparisons of signals partly masked by noise, and the subharmonic pitches of a pure tone at low S/N ratio.

CHAPTER 3: The Role of Stimulus Uncertainty in the Discrimination of Auditory Patterns

Charles S. Watson and William J. Kelly

Boys Town Institute for Communication Disorders in Children,

A review of earlier research on the discrimination of simple and complex sounds, together with experiments we have conducted with tonal sequences, suggests that information may be extracted from word-length auditory patterns by application of highly efficient mechanisms of selective auditory attention, in a two-stage process. A descriptive model is proposed, according to which the first stage in the processing of word-length patterns is assumed to be a crude analysis of the overall pitch/prosody contour of the pattern. Processing within the first stage results in the assignment of a pattern to a class or subset, all of the members of which carry their identifying information at the same spectral/temporal points within the pattern. Processing within the second stage results in precise resolution of the

pattern waveform in the high-information bearing region(s). The primary limitation on the discriminability of complex auditory patterns is proposed to be that of stimulus uncertainty, which has its major effect on the first stage of the processing model.

CHAPTER 4: Meaningfulness and the Perception of Complex Sounds

John C. Webster

Rochester Institute of Technology

In recent years, computer-aided statistical decision techniques based on electronic and/or visual analyses have proven to be powerful tools for classifying passive sonar signals. Nonetheless, they have not equalled the capabilities of the human auditory system in classifying these complex sounds. This chapter reviews the author's experimental work over a number of years on human perception of complex sounds and on the role of meaningfulness and familiarity in signal identification.

CHAPTER 5: Speech Perception and Auditory Processing

A. W. F. Huggins

Bolt Beranek and Newman Inc.

The recognition of spoken words is perhaps our most highly developed form of auditory signal classification. A large part of this skill is dependent on the top-down processing and recoding of the input that is made possible by the involvement of language. Other contributing factors are (1) the fact that the listener himself has a vocal tract that is functionally identical to the one that produced the signal he must classify; and (2) the temporal patterning of speech, the importance of which has only recently been appreciated. Although the early stages of bottom-up processing of speech show some strong similarities to processing of non-speech signals, it is not clear to what extent useful parallels can be drawn at higher levels. This uncertainty is reflected in a current controversy in the study of speech, summarized in the question: "Is speech special?"

SECTION II: PERCEPTION OF COMPLEX VISUAL PATTERNS

CHAPTER 6: Negligible Symmetry Effects in Dot Pattern Detection

William R. Uttal and Thelma E. Tucker

University of Michigan

Both information and autocorrelation theories predict that symmetry should play a substantial role in human form perception. Though it has long been known that symmetry effects in memory studies are substantial, recent evidence suggests that they are small in detection tasks. In the present work, it is further shown that symmetry effects in a task involving dotted target detection in dotted visual noise are negligible. This finding adds further support to a multistage model of visual form perception.

CHAPTER 7: A Psychophysical Approach to Dimensional Integrality

Robert G. Pachella, Patricia Somers,
and Mary Hardzinski

University of Michigan

A theory of dimensional integrality is presented in which the critical defining characteristic of integral visual displays is the lack of correspondence between the physically defined display dimensions and the attributes of the display that can be perceived by an observer. To the extent that the physical dimensions of a display correspond to the psychological attributes, the dimensions will be separable; to the extent that they don't correspond, the dimensions will be integral. Two forms of data are presented. First, multidimensional scaling data are presented, which define these complex psychophysical mappings for various sets of stimuli. Second, reaction time data, utilizing these scaled stimuli, are presented demonstrating how this psychophysical correspondence can lead to patterns of results that had previously been associated with the issues of integrality and separability of display dimensions.

SECTION III: THEORETICAL APPROACHES TO PATTERN RECOGNITION

CHAPTER 8: A Feature Extraction Approach to Auditory Pattern Recognition

Julius T. Tou

University of Florida

Automatic recognition of auditory patterns is becoming a subject of considerable interest among psychologists. This chapter introduces some techniques of automatic classification and feature extraction which are applicable to auditory patterns. Cluster-seeking and feature extraction approaches are discussed. The Karhumen-Loeve expansion of auditory patterns provides a method for analysis and extraction of features. Computer techniques for feature extraction are discussed in which eigenvalues are used to represent the features. It is found that larger eigenvalues of the correlation matrix for auditory pattern vectors carry more information for discrimination of the auditory pattern.

CHAPTER 9: Pattern Recognition in Ocean Acoustics

Arthur E. Bisson

Naval Ship Research and Development Center

From childhood we are trained to recognize and identify out-of-sight events and occurrences by means of only the acoustic noise produced. The slam of a car door, footsteps in the hall, rain outside the window all can be identified by distinguishing characteristics or patterns that differentiated one sound or group of sounds from the other. How does man recognize or discriminate one sound from another? What are the basic features or characteristics of sounds that he uses to discriminate? Although questions regarding man's learning and recognition process are not easily answered, we do have at our disposal a formalism that aids to identify and utilize distinct features of sounds to classify. This formalism is called syntactic pattern recognition. This chapter is devoted to an overview of pattern recognition as it applies to the classification of acoustic sounds in the ocean.

SECTION IV: MULTIDIMENSIONAL PERCEPTUAL SPACES

CHAPTER 10: Auditory Perception: Recommendations for a Computer Assisted Experimental Paradigm

Forrest W. Young

University of North Carolina

and

Cynthia H. Null

College of William and Mary

It is argued that understanding the perception of auditory stimuli is a necessary precursor to understanding their recognitiion and classification. Recommendations for a computer-assisted experimental paradigm to investigate auditory perception are presented. The recommendations focus on the use of digitized stimuli, multidimensioanl scaling and multi-set matching. The design should permit results which: (a) emphasize individual differences; (b) are relatively free from experimenter bias; (c) are highly replicable; and (d) are validated.

CHAPTER 11: Multidimensional Perception Spaces; Similarity Judgment and Identification

David J. Getty, John A. Swets and Joel B. Swets

Bolt Beranek and Newman Inc.

This chapter explores the relationship between the perceptual representation of complex stimuli and decision processes. A model of similarity-judgment and identification processes is presented that assumes (1) that complex stimuli are represented perceptually as points in a multidimensional geometric space, (2) that similarity judgments are inversely related to interstimulus distance in the perceptual space, and (3) that identification judgments are described by a probabilistic decision rule based on the pattern of interpoint distances in the perceptual space. The model is shown to accurately predict individual identification confusion matrices. The results suggest that observers' identification and similarity

judgments are based on an adaptive weighting of the perceptual dimensions. This optimization process is both stimulus and task dependent.

CHAPTER 12: Feature Selection in Auditory Perception

James H. Howard, Jr. and James A. Ballas

The Catholic University of America

Feature extraction plays an important role in theoretical accounts of auditory classification. Auditory features are generally taken to represent the "essential" perceptual elements of a complex sound. The feature selection problem concerns the definition of these basic elements. Two approaches to auditory feature selection are briefly reviewed. The results of three experiments are interpreted as supporting the more flexible of these approaches.

APPENDIX A

SYMPOSIUM ON THE RECOGNITION AND CLASSIFICATION OF AURAL (NON-SPEECH) SIGNALS

June 28-30, 1978

Bolt Beranek and Newman Inc.
Cambridge, Massachusetts 02238

Co-Organizers:

David J. Getty
Bolt Beranek and Newman Inc.

James H. Howard, Jr.
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Wednesday, June 28

I. INTRODUCTION

DAVID J. GETTY
JAMES H. HOWARD, JR.

II. PERCEPTION OF COMPLEX AUDITORY PATTERNS

FREDERICK L. WIGHTMAN
(Northwestern University)

"Pitch Perception--An Example of Auditory Pattern Recognition."

REINIER PLOMP
(Institute for Perception TNO)

"Perception of Sound Signals under Unfavorable S/N Ratios."

CHARLES S. WATSON
(Boys Town Institute for Communication Disorders in Children)

"Physical and Psychological Factors in the Discrimination in Word-Length Auditory Patterns."

JOHN C. WEBSTER
(Rochester Institute of Technology)

"Meaningfulness and the Perception of Complex Sounds."

A. W. F. HUGGINS
(Bolt Beranek and Newman Inc.)

"Speech Perception and Auditory Processing."

Thursday, June 29

III. PERCEPTION OF COMPLEX VISUAL PATTERNS

WILLIAM R. UTTAL
(University of Michigan)

"Complexity and Symmetry Effects: Limitations of an Autocorrelation Theory of Form Detection."

ROBERT G. PACHELLA, PATRICIA SOMERS, and MARY HARDZINSKI
(University of Michigan)

"A Psychophysical Approach to the Problem of Dimensional Integrality."

IV. THEORETICAL APPPROACHES TO PATTERN RECOGNITION

JULIUS T. TOU
(University of Florida)

"Feature Extraction in Auditory Pattern Recognition."

ARTHUR E. BISSON
(Naval Ship Research and Development Center)

"Overview of Importance of Automatic or Semi-Automatic/ Man-Machine Classification in the Ocean Environment."

THEODOSIOS PAVLIDIS
(Princeton University)

"Structural Pattern Recognition."

V. MULTIDIMENSIONAL PERCEPTUAL SPACES

FORREST W. YOUNG and CYNTHIA H. NULL
(University of North Carolina)

"Auditory Perception: Recommendations for a Computer-Assisted Experimental Paradigm."

Friday, June 30

DAVID J. GETTY, JOHN A. SWETS, JOEL B. SWETS
(Bolt Beranek and Newman Inc.)

"Multidimensional Perceptual Spaces Revealed by Multidimensional Scaling Procedures: Fact or Fiction?"

JAMES H. HOWARD, JR., and JAMES A. BALLAS
(Catholic University)

"Feature Selection in Auditory Perception."

VI. GENERAL DISCUSSION

JOHN A. SWETS
(Bolt Beranek and Newman Inc.)

Summary Remarks and Discussion

APPENDIX B

LIST OF ATTENDEES

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